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SUPERABRASIVE MATERIAL PROCESSES & TESTING

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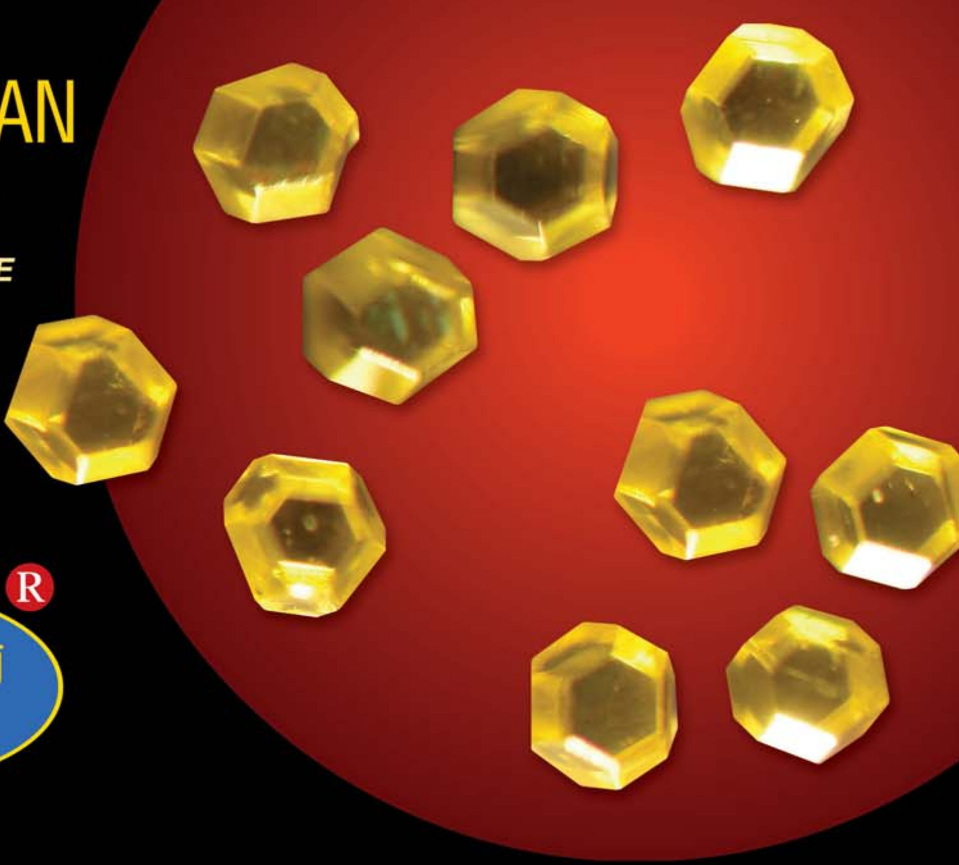

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COVER PHOTO

Developments in PCD, PcBN, Wire Dies and other polycrystalline materials continues as demands increase for higher productivity and lower manufacturing production costs.

Photo courtesy of Diamond Innovations.

FINER POINTS is the oldest publication devoted exclusively to the understanding, selection and application of diamond, cubic boron nitride and related materials. It is edited for recipients who are involved in some way with these "superabrasives", either as providers of the materials, producers of products containing the materials or users of these products (e.g., grinding wheels, dressing tools, drill bits, saw blades, sawing wires, cutting tools, polishing compounds, CVD film products, etc.).

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A Finer Point of View…

Over the last 10-15 years China has emerged as the largest producer of diamond in the world, I, like many, have been following with increased interest the evolution of the quality of Chinese diamond. China has acquired a reputation for flooding the world market with low cost/low quality diamond which has been mainly used in less challenging applications. However, in recent years, the quality of many Chinese diamond grades (particularly saw diamond) has greatly improved while the cost advantage has been maintained the result being the commoditization of the synthetic diamond market. The fact that Chinese diamond has received recognition outside China is documented by import statistics of many countries, including U.S.

On a recent trip to China, I had the opportunity to learn of some technological developments by a select number of diamond synthesizers, which contributed primarily to the improvement of the quality of Chinese saw grade diamond. Based on recent development of the belt-like cubic press process, which combines the advantages of both belt and cubic HPHT processes, coupled with the implementation of the well established powder capsule technology and the indirect heating technique, high quality, large grit-size saw grade diamond is being now produced in large quantities in China. However, given the large number of diamond synthesizers, and the differing levels of technological advancement, consistency of the Chinese diamond grades still represents a tremendous challenge for both the diamond synthesizers and the end users. Despite world-class business and manufacturing capabilities, China still suffers from its reputation of a copycat manufacturer. The lack of technological know-how, systems integration, and the ability to design new products from scratch and get them to the manufacturing line, still represent obstacles they need to overcome. However, this will likely happen sooner rather than later.

I use the evolution of the quality of Chinese saw grade diamond as an attempt to illustrate the mechanics of today's world superabrasives industry and, hopefully, to convey a message: the need for increased U.S. R&D efforts in all areas of superabrasives industry. Unfortunately, the 2008 National Science Board report entitled "U.S. Basic Research: A Need for Serious National Attention", signals with concern the stagnation and even decline in some areas, in support for R&D and especially basic research. In light of the growing importance of knowledge-based industries in the global economy, these trends are particularly alarming. The confluence of these indicators raises important questions regarding the future of U.S. competitiveness in international markets and the future existence of highly skilled jobs at home. Add this disturbing trend, to the well-known history the U.S. has in watching other countries capitalize on what were originally American innovations (i.e. VCR, magnetic levitation train, silicon chip, computer, etc.) and one is asked to question the long term prospective of the U.S. superabrasives industry. The manufacturing, selection, qualification, and use of superabrasive products are becoming ever more complex. Add to that the competitive pressure from outside the U.S. and the need for increased U.S. R&D within the superabrasives industry becomes greater than ever. I believe the IDA member companies should take into account these trends when formulating their long-term strategies. We should understand these challenges (particularly the steps the Chinese have taken to further themselves in the superabrasives industry), and use our creativity and R&D capabilities to continually innovate and stay ahead. As a matter of fact, many of the superabrasive products and technologies have been discovered in this country and then duplicated elsewhere. The IDA should be the conduit for the U.S. superabrasives industry to unite and grow in strength and technology, by promoting the IDA members not only to the abrasives market, but also to US government agencies to gain funding for R&D in our industry.

PRESIDENT
Ion C. Benea, Ph.D.

Hopefully, we can all overcome our fear generated by the current recession, and look further to the future to make sure we have one tomorrow.

Sincerely,

Ion Benea

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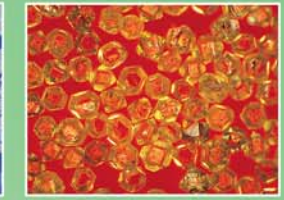

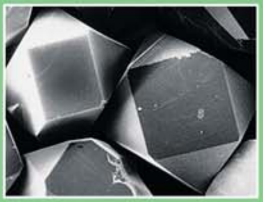

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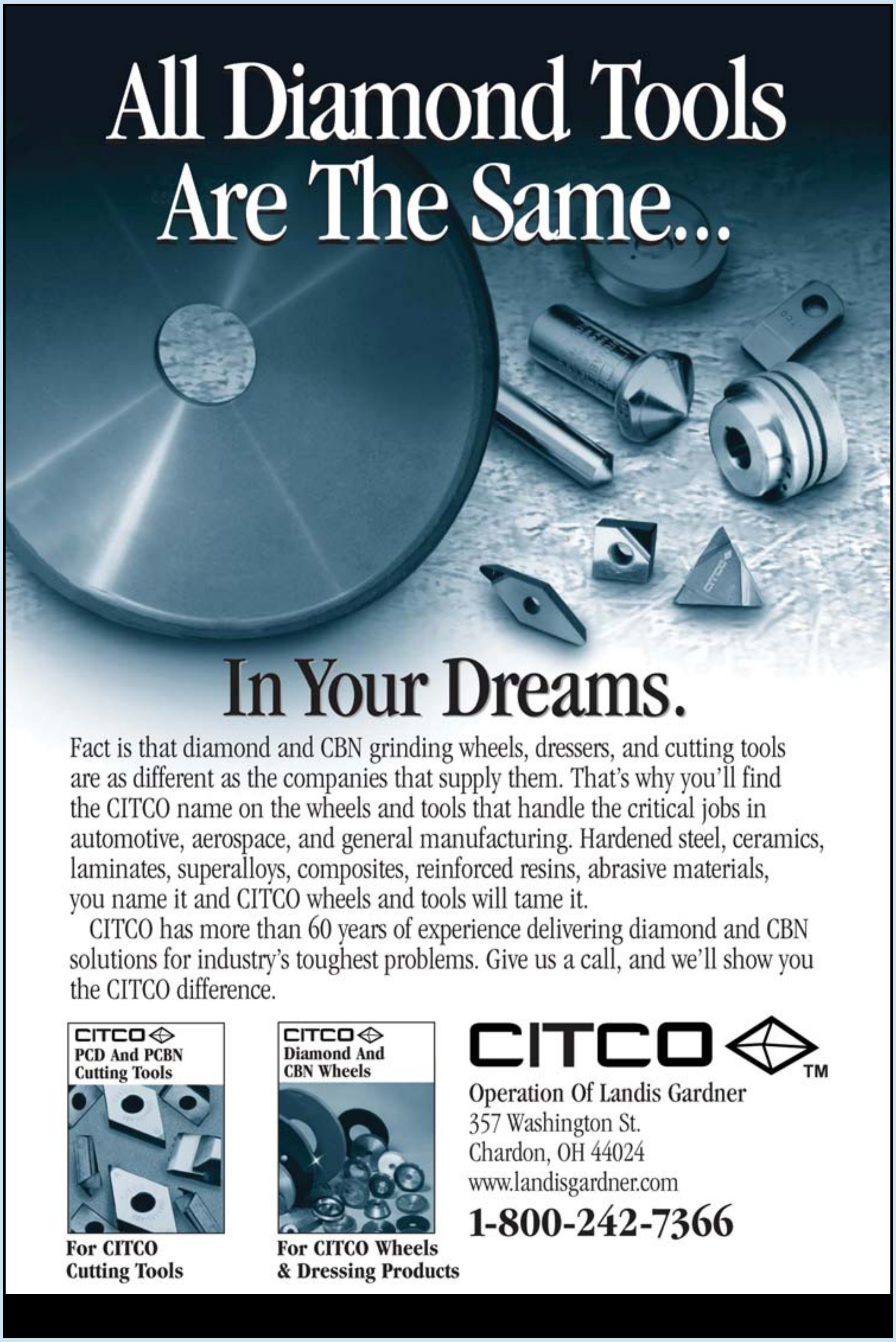
FINDING PURE HARMONY IN INTERNATIONAL TRADE

Terry Kane, Editor

The international community has established a Harmonized System of numbering import and export products and ***any business selling to an international customer has to assign a Harmonization System code number to shipped products***. Harmonization Codes are specific identifiers for a commodity. This number is an aggregate series starting with a broad two-digit category range. *For instance, 68-71 is everything under "Stone & Glass". Next comes a two-digit identifier such as 71, which are "Pearls, stones, precious metals, imitation jewelry, coins etc". Then is a 4-digit identifier like 7102, which is "Dust & powder of natural or synthetic precious or semiprecious stone". A 6-digit identifier defines the commodity a little further such as 710510 "Dust and Powder of Diamonds" and then some commodities are taken 10 digits as 7105100025 "Diamond dust or powder synthetic".* The Harmonized System Committee of the World Customs Organization created the 4 and 6-digit codes. As signatories to the Harmonized System Convention, the USA and all trading partners use these 4 and 6-digit codes for national tariff schedules. Beyond the 6-digit level, the US Congress establishes the 8-digit codes, their descriptions and their duty rates. At the 10-digit level, the U.S. International Trade Commission (USITC) meets twice a year to consider requests from other Government agencies, trade associations, etc., for statistical breakouts of products. Over the last couple of years the Industrial Diamond Association of America (IDA) has been working to better define product breakouts in the superabrasives industry for the Harmonization System. Our next step is to determine which products can be listed separately. The Committee has three criteria for product breakout: (1) there must be at least $1 million annual trade; (2) the trade to be reported under the new product breakout must not violate Census rules of confidentiality; and (3) the descriptions must be clear and administrable for Customs. The USITC is responsible for maintaining and updating the Harmonized Tariff Schedule of the United States, but US Customs and Border Protection interprets and administers the tariff, including classification, duty assessment and collection, valuation, country-of-origin determinations, procedures, etc. Since all participating countries report export and import data, individual companies can see which countries are involved, and to what degree, in industries of interest. The IDA receives these reports quarterly so members can review International Trade Data for superabrasive products. To assign the proper code is extremely important because these codes can determine what the tariff may be on products shipped. An improper code may result in a higher tariff being levied on a given product, for instance raw material would probably be less than a finished tool. We have found many companies are reporting specific products like PCD, PcBN, cBN and CVD Diamond, which do not have their own code, under different codes. We noticed that there was no specific classification for these products in our industry. Diamond is listed, as are diamond wheels, but no listing exists for cBN wheels, polycrystalline materials or CVD diamond. The IDA is working to classify specific products in our industry to reduce tariffs and to accurately track imports/exports. Accomplishing this project will be a tremendous value to the IDA, its members and the industry as a whole, which will be pure harmony for the international trade of superabrasives.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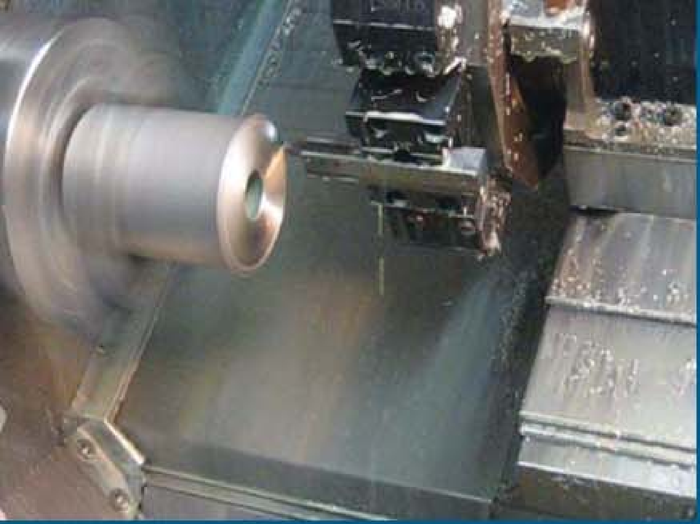


A New Low Cost Accelerated PCD Abrasion Test Method

By: David Slutz & Richard Clark
Morgan Carbon

ABRASION TEST QUICKLY AND COST-EFFECTIVELY DISTINGUISHES PRODUCT DIFFERENCES

The typical abrasion test for cutting tool products involves measurement of the flank wear of a single point cutting tool as a ratio of the volume of work piece removed under constant cutting conditions. The preferred work-piece materials used for such a test are A390 aluminium, A394 aluminium, and Duralcan™. These materials are chosen for their high silicon or silicon carbide (>17%) content. The high silicon or silicon carbide content is responsible for the abrasiveness of these materials. A highly abrasive work-piece is desirable in order to reduce the required volume of work-piece removed before end of life flank wear has occurred on the PCD cutter edge. This also reduces the time required to wear a PCD tool to this end-point. Reducing the volume of the work-piece required and the time to perform the test reduces the overall cost of performing the test.

THE ABRASION TEST IS USUALLY PERFORMED BY ONE OF THE FOLLOWING TWO METHODS

Turning the OD

A typical single point cutting tool is manufactured in the configuration shown in **Table 1**. The single point cutting tool is used to machine the outer diameter of a work-piece for a set length along its outer diameter. Typical conditions used are shown in **Table 2**. Measurements of the work-piece and the PCD flank wear are made at defined times or after a defined number of passes. The test is considered complete when the flank wear equals or exceeds 0.015". One advantage of this method is the constant spindle speed used for each pass. The spindle speed needs to be increased on each successive pass in order to maintain a constant surface speed and this can be done on a simple lathe, without CNC capability. One disadvantage of this method is that for each successive pass, the volume of work-piece removed decreases, reducing data linearity. In addition, the maximum spindle speed for the machine will limit the final diameter of the work-piece that will maintain the desired surface speed. Another disadvantage of this test method is that each pass may not be cutting the same abrasiveness of material. Work-piece materials such as cast aluminium alloys may have variations in the material properties, including abrasiveness, from outer diameter to inner diameter. The effect of this can be somewhat mitigated by ensuring each tool cuts from maximum diameter to minimum diameter for each test.

Table 1: **Typical Single Point Cutting Tool Dimensions**

SINGLE POINT CUTTER	90T5.0-3.2P
Shank Width & Height	9.525 mm
Shank Length	52 mm
Rake Angle	+0°
Relief Angle	10°
Nose Radius	1.016 mm
Edge Prep	up-Sharp

Table 2: **Typical Parameters for Turning Test**

MACHINING PARAMETERS	ENGLISH	METRIC
Surface Speed	2000 ft/min	610 m/min
Feed Rate	0.010 in/min	0.254 mm/rev
Depth of Cut	0.020 in.	0.508 mm
Lead Angle	45°	45°

Face off Surface of Cylindrical Tube

The second method is to face off the front surface of a cylindrical tube. This method has the advantage that for every pass, the same volume of work-piece is removed. In addition, the test removes a complete sample of material from inner diameter to outer diameter, so if there are any radial variations in the material each pass gets a consistent representative sample of the work-piece. In order to maintain constant surface speed, the spindle speed needs to increase as the cut progresses from outer diameter to inner diameter. Consequently, this test does require a CNC lathe. The same single point cutter configuration and machine parameters can be used as shown in **Table 1** and **Table 2** respectively.

Table 3: **4032F Abrasion Test Machine Parameters**

MACHINING PARAMETERS	ENGLISH	METRIC
Surface Speed	1500 ft/min	457 m/min
Feed Rate	0.010 in/min	0.254 mm/rev
Depth of Cut	0.020 in.	0.508 mm
Lead Angle	45°	45°

DISCUSSION & RESULTS OF EXPERIMENT

The initial intention of this experiment was to make a comparative study of the abrasiveness of PCD materials manufactured by the leading global PCD companies. Samples of similar grades were obtained from these PCD manufacturers for this test matrix. All samples had a polished surface and were 3.2 mm thick. Several triangular pieces were cut from each blank. The triangles were then fabricated into single point cutting tools to the specifications in **Table 1**.

At the time of the first experimental test, the preferred work-piece materials were not available, so an alternative material was used. The readily-available 4032F aluminium alloy was chosen. This material contains 12.2% silicon and therefore was expected to be less abrasive than A390, A394, or Duralcan™. It was anticipated that it would require more material to complete the test. We purchased several billets of material of dimensions 4.5" diameter and 18" long.

4032F Test Results

Table #3 gives the machining parameter used in the 4032F test. The surface speed was reduced from 2000 SFM to 1500 SFM. This was done because the machine being used for the test had an upper spindle speed limit of 3400 rpm. By reducing the surface speed from 2000 to 1500 we then decreased the minimum diameter of work-piece from 2.25" to 1.68". This allowed for an additional 30.5 in3 of material to be removed per billet. **Table 3** gives the machining parameters used in the test and **Figure 1** shows a photograph of the turning test described above.

Table 4: Tungsten Carbide Abrasion Test Machine Parameters

MACHINING PARAMETERS	ENGLISH	METRIC
Surface Speed	50 ft/min	15 m/min
Feed Rate	0.005 in/min	0.127 mm/rev
Depth of Cut	0.010 in.	0.254 mm
Lead Angle	45°	45°

Table 5: Modified Tungsten Carbide Abrasion Test Machine Parameters

MACHINING PARAMETERS	ENGLISH	METRIC
Surface Speed	70 ft/min	21 m/min
Feed Rate	0.003 in/min	0.076 mm/rev
Depth of Cut	0.010 in.	0.254 mm
Lead Angle	45°	45°

Two PCD single point tools were tested on one 4032F billet. The abrasiveness of 4032F was not sufficient to wear out the two single point cutters using one 4032F billet. Typically the end of test would be after 0.015" of flank wear on the PCD cutting edge. However, after 140 in3 of alloy removal, both PCD tools had less than 0.002" of wear. Although additional 4032F billets were purchased, delays in its shipment prevented completion of the test. The results of the partial test appear in **Figure 2**. Without more 4032F work-piece material to continue the test, it became necessary to find an alternative material with much higher abrasive properties. A 13% cemented tungsten carbide cylindrical tube was available and it was decided to utilize this, even though it was anticipated that the material might have been too abrasive for a meaningful test to be developed. The following sections describe the experimental method developed for a single point cutter turning cemented tungsten carbide.

13% Tungsten Carbide Test Results

The cemented tungsten carbide work-piece had the following dimensions: 3.066" OD x 1.644" ID x 1.463" length. Since the work-piece was a tube, the face off of the front surface method was utilized instead of the OD turning method.

Two PCD samples were tested using the machining parameters in **Table 4**. The results appear in **Figure 3**. The abrasiveness of the tungsten carbide was more than 1000 times the abrasiveness of the

Table 6: Abrasion Test Results

	VOLUME REMOVED in³	FLANK WEAR in	COMMENT
Sample A	0.138	0.0126	OK
Sample B	0.142	0.0131	OK
Sample C	0.117	0.0139	Chipped @ 0.117
Sample D			Accidentally broke on first pass
Sample E	0.127	0.0138	Chipped @ 0.127
Sample F			Not available for this test
Sample G			Not available for this test

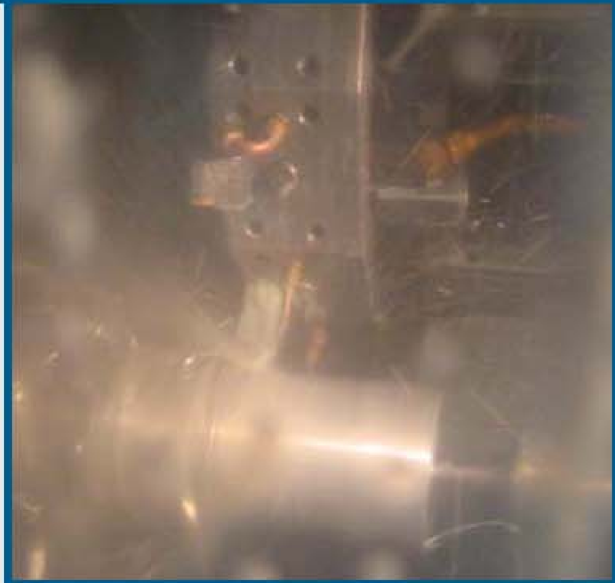


Figure 1: Photo of PCD Cutting 4032F Aluminum Alloy

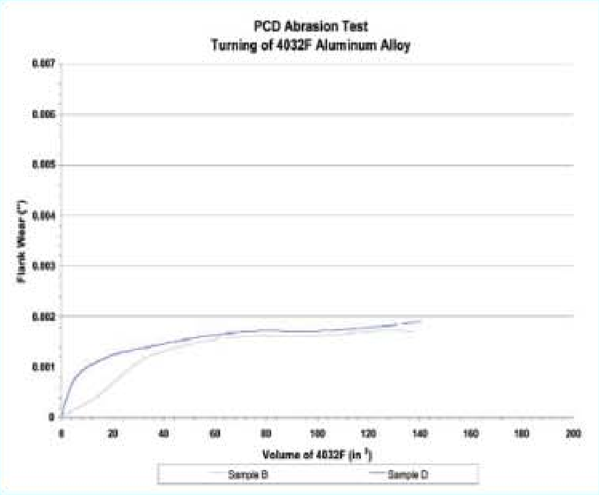


Figure 2: Abrasion Test Results in 4032F

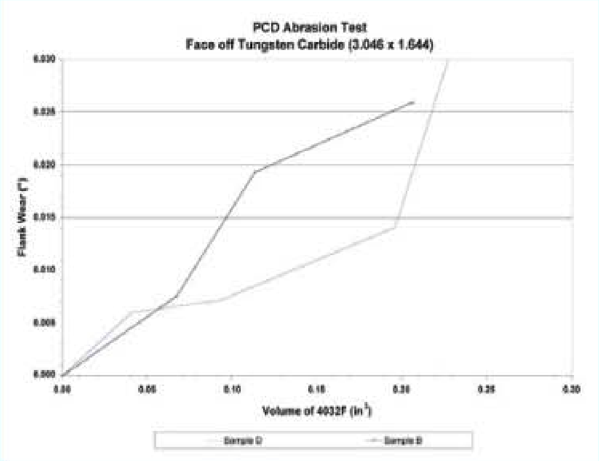
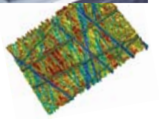


Figure 3: Abrasion Test Results for Tungsten Carbide

NEWS *and* notes

ENGIS LABORATORY OFFERS ADVANCED MATERIALS EXPERTISE

– Leading developer of diamond superabrasive finishing systems for the manufacture of MEMS, data storage components, optics and opto-electronics, Illinois-based Engis Corporation has created an Advanced Materials Processing Laboratory to provide a resource for developers seeking technical support and expertise in polishing and thinning of advanced materials. In this laboratory expert staff work directly with manufacturers and researchers to solve the technical challenges posed by processing the multitude of new materials now being used in the production environment. Engis provides products, services and technological advances in several key areas including: diamond flat lapping/polishing, diamond and CBN-plated tools, bore finishing tools and machines, tool room products and accessories along with R&D and technical support. For further information visit www.engis.com



VOLLMER OF AMERICA HOSTED THE ISKA (International Saw and Knife Association) SEMINAR

– The seminar was held at their US headquarters in Carnegie, Pennsylvania. Over 50 attendees representing 28 different companies were present to hear guest speakers discuss sharpening of HSS and Carbide Saws, selection of grinding wheels, overviews of diamond tooling, and measuring techniques. The speakers represented six different companies from North America and Europe.

ABRASIVE TECHNOLOGY ANNOUNCES ENHANCED WEBSITE

– *Lewis Center, OH, July 9, 2009* – Abrasive Technology, a worldwide leader in the manufacturing of superabrasive grinding and tooling products, is pleased to announce an enhanced version of its website: www.abrasive-tech.com. The new version features a bright, new look on the home page, with improved access to product offerings and information, while maintaining the site's existing e-commerce capabilities. Features of the enhanced site include: Company product capabilities, New functionality allowing visitors to self select how Abrasive Technology can best serve their needs, a new Spotlight section showcasing the Company's latest news and products and on-line literature. Additionally customers may continue to order on-line, as well as access their order history, quotes, open orders and invoices.

HAAS INTRODUCES LIMITED-EDITION TONY STEWART MACHINE!

– *Oxnard, CA* – To commemorate the historic partnership between celebrated NASCAR driver Tony Stewart and Haas Automation founder Gene Haas – co-owners of Stewart-Haas Racing – Haas Automation is building a Limited-Edition Tony Stewart VF-2SS VMC. The Limited-Edition (Haas Automation will build only 75 of these specially designed machines during 2009) Tony Stewart Haas VF-2SS features a special racing paint scheme, and sports decals of Tony's signature and the No. 14 of his NASCAR ride. To complete the look, the Stewart-Haas Racing logo is etched in stainless steel below the machine's control pendant. "The Tony Stewart VF-2SS provides legendary Haas performance in a great looking, race-inspired package," said Gene Haas. Each will feature an engraved and numbered aluminum plaque personally signed by Tony Stewart, and include a certificate of authenticity. For further information contact: E-Mail: srathburn@haascnc.com or visit: www.haascnc.com

CITCO HIRES NEW SALES & MARKETING DIRECTOR

– *Chardon, OH* – John Leone has been hired as Director of Sales and Marketing of CITCO, a specialist of diamond and cBN products, forming with Gardner Abrasives the Consumables Operations of Cinetic Landis Corp., members of the Fives Cinetic Division of the global Fives Group of companies. John Leone comes to CITCO with an extensive sales and marketing background in industrial highly engineered products. He has worked with direct sales personnel, independent manufacturer's representatives and distributors worldwide. Mr. Leone has been active member of many professional organizations including the SAE and a committee member for the SPE.

FOR IMMEDIATE RELEASE TYROLIT IS NOW OFFERING WEBINARS.

– Webinar is short for Web-based seminar, a presentation, lecture, or seminar that is transmitted over the Web. A key feature of a Webinar is its interactive elements both presenter and the audience are able to communicate in this forum. This format allows TYROLIT to provide the customer with a cost-effective solution for training. TYROLIT conducted its first webinar on Tuesday, March 31st and another in June 2009. The webinar, Thinking Super - Superabrasive Tooling was attended by eight different companies. For more information contact Jamie Crowe Jamie.

Table 7: Abrasion Test Results

	VOLUME REMOVED in^3	FLANK WEAR in	COMMENT
Sample A	0.0468	0.0105	Broke @ 0.0338
Sample B	0.1170	0.0140	OK
Sample C	0.0351	0.0140	Broke @ 0.0317
Sample D	0.0819	0.0147	OK
Sample E	0.0936	0.0140	OK
Sample F	0.0819	0.0143	Chipped @ 0.0349
Sample G	0.1404	0.0135	OK

4032F material. This meant that only three to four passes were required to establish a flank wear exceeding 0.015". It is desirable to have at least ten data points to establish the 0.015" flank wear in order to define the wear curve. This carbide work-piece was therefore too large to be suitable for an abrasion test.

13% Tungsten Carbide (reduced size) Test Results

The next test used a 13% tungsten carbide work-piece with dimensions 1.282" x 0.618" x 2.242". Five PCD single point cutting tools were fabricated. Each was tested using the machining parameters in Table 4. Figure 4 is a photo of the test in progress. Figure 5 gives a plot of the flank wear versus volume of work-piece removed. In each case, the single point cutter chipped prematurely ending the abrasion test.

Another test was then conducted using less aggressive machining parameters. The surface speed was increased and the feed rate was lowered in order to reduce the stress on the cutting edge. Table 5 gives the machining parameters used in this experiment. Five single point cutting tools were fabricated using PCD from the same manufacturers as per the previous test. Figure 6 gives a plot of the flank wear versus the volume of work-piece removed. Table 6 shows the flank wear and volume of work-piece removed at the end of each test. Sample D was accidentally broken on the first pass and a spare was not available to continue the test. The remaining four tools all produced the normal S-shaped curve for abrasive wear and the end of test was when the flank wear met or exceeded 0.015". Samples A and B were the best performers and sample C was the worst. The ranking for the four tools are as follows (best to worst) Sample B→ A→ E→ C.

The above experiment did not have three of the cutting tools from the intended PCD manufacturers. Therefore the last test was repeated with tools from all included PCD manufacturers. The machining parameters used for this experiment were as shown in Table 5. The results appear in Figure 7 and in Table 7. Sample G had the best performance with sample B being a close second. Sample C was the worst performing PCD in this test. The results for sample A were inconclusive since the tool was accidentally chipped during handling.

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Table 8: Duraclan™ Abrasion Test Machine Parameters

MACHINING PARAMETERS	ENGLISH	METRIC
Surface Speed	2000 ft/min	610 m/min
Feed Rate	0.005 in/min	0.127 mm/rev
Depth of Cut	0.020 in.	0.508 mm
Lead Angle	45°	45°

Table 9: Duralcan™ /abrasion Test Results

	VOLUME REMOVED in^3	FLANK WEAR in	COMMENT
Sample A	144	0.0100	OK
Sample B	125	0.0070	Tool dropped and chipped edge
Sample C	112	0.0098	OK
Sample D	13.8	0.0021	Ran out of Duralcan™
Sample E			Not Tested
Sample F			Not Tested
Sample G	149	0.0100	OK

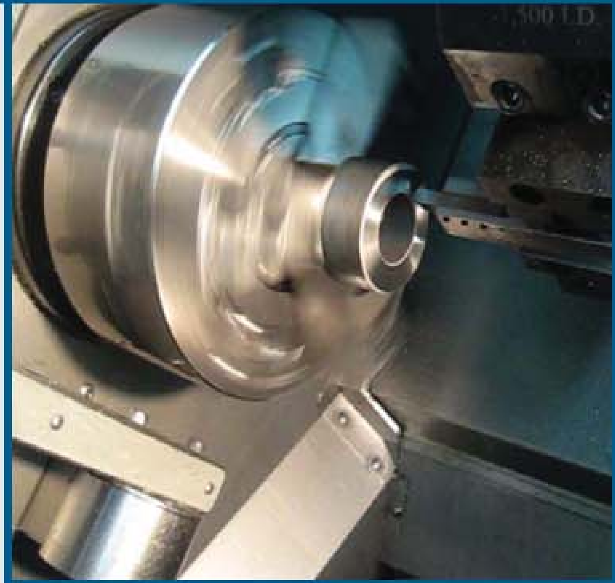

Figure 4: Photo of the Tungsten Carbide Accelerated Abrasion Test

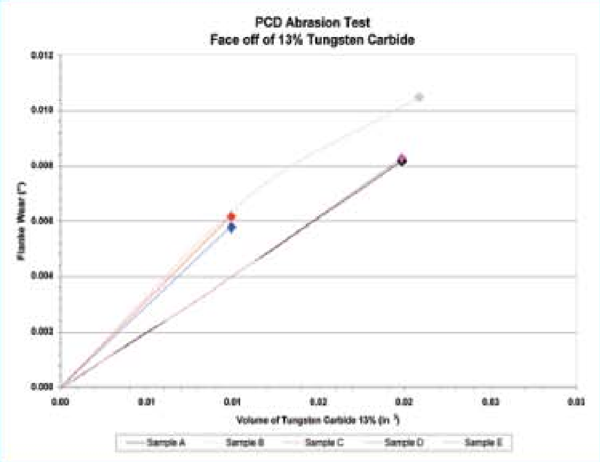

Figure 5: Abrasion Test Results for Tungsten Carbide (reduced size)

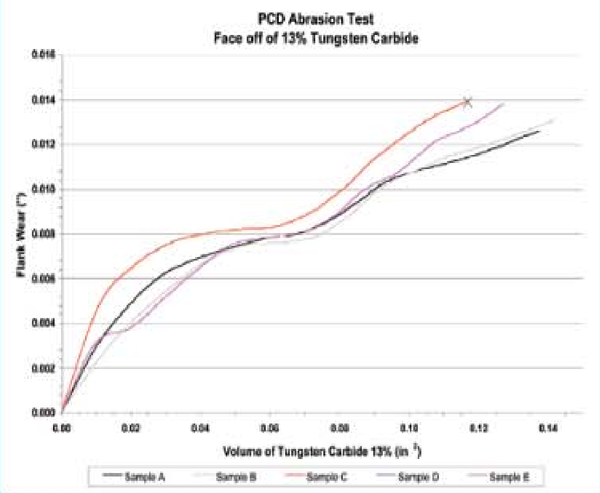

Figure 6: Tungsten Carbide Abrasion Test Results (reduced size)

Typical Applications of DURALCAN™ Products
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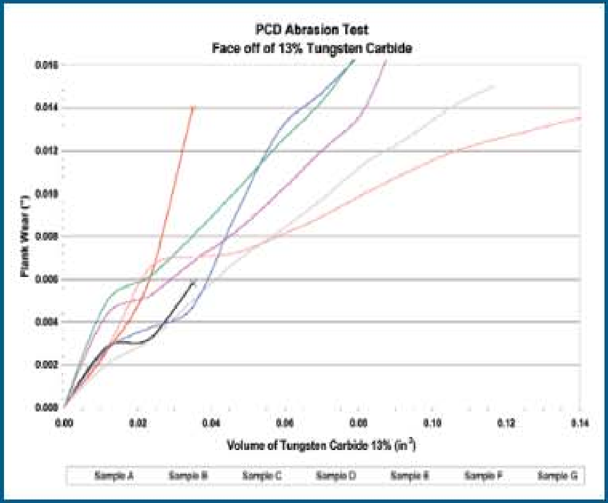


Figure 7: **Tungsten Carbide Abrasion Test Results (reduced size)**

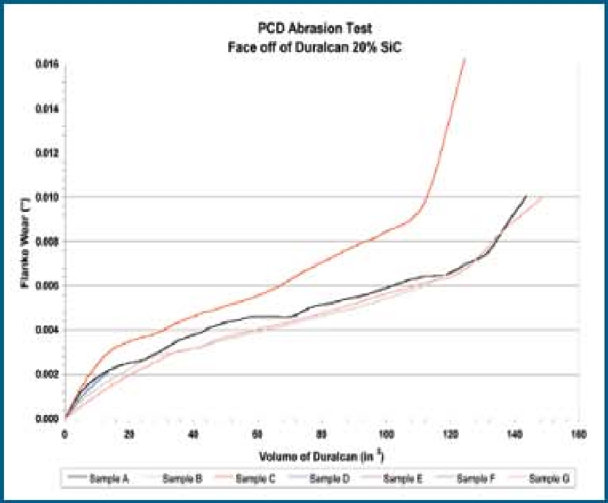


Figure 8: **Duralcan™ Abrasion Test Results**

Samples E and F were very similar and not quite as good as sample B. The overall ranking (best to worst) was Sample G→ B→ E→ F→ D→ C.

Duralcan™ Test Results

To ensure that the ranking of the PCD materials in the previous test is consistent with that which would be derived using conventional work-piece test material, such as Duralcan™, an additional experiment was conducted. This experiment used the same single point cutting tool design with PCD from the same manufacturers. The work-piece used was Duralcan™, made with 20% SiC. The work-piece dimensions were 4-1/2" x 2" x 12". The machining parameters for this experiment are shown in **Table 8**. Unfortunately sufficient work-piece material was not available at the time of testing so only four of the tools were tested. The results appear in **Figure 8** and **Table 9**. Sample B testing ended prematurely when the tool was chipped in handling. However, the results are similar to that obtained in the carbide test. Samples A, B and G all had similar results with G being slightly better than A or B. The ranking for the four samples (best to worst) is Sample G→ B→ A→ C

Table 10: **Cost of Work-piece Material**

WORK-PIECE	DIMENSIONS	USABLE VOLUME in³	COST	US$/in³
4032F Al Alloy	4-1/2" x 18"	239	$4,995.00	20.88
Duralcan™ 20%	4-1/2" x 12"	147	$238.00	1.62
Tungsten Carbide	1.3" x 0.600" x 4.0"	3.96	$157.00	39.60

COST ANALYSIS

The price for the 4032F material was very high and lower cost vendors might be available. The Duralcan™ material was far less expensive, but was difficult to obtain. The tungsten carbide had the lowest cost per piece and is readily available in low quantities. **Table 10** give the cost of each of the work-piece materials and a calculation of the cost per volume of material. Note the tungsten carbide is the most expensive on a per volume basis.

The cost to perform an abrasion test to completion for any given PCD tool was then calculated for each of the work-piece materials. The results appear in **Table 11**. The lowest cost test was the tungsten carbide because the abrasiveness of the tungsten carbide is ~1000x greater than the other materials. Therefore very little work-piece is required to perform the test. In addition, since the tungsten carbide test requires so little material the necessary machine time is much lower and as a result the labor time is the lowest at well. It is estimated that the time to compete a test is less than 2 hrs. Another advantage is for one carbide work-piece approximately 25 PCD tools can be tested.

Table 11: **Cost and Time to Perform an Abrasion Test**

* Estimated Endpoint

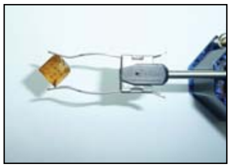
WORK-PIECE	VOLUME in³ per TEST	COST per TEST	MACHINE TIME	LABOR TIME
4032F Al Alloy	5002*	$104,454.26	31.46	6.5
Duralcan™ 20%	153	$248.35	3.23	2.25
Tungsten Carbide	0.16	$6.28	1.84	1.92

Table 12: **Abrasion Test Ranking**

TEST	RANKING (Best to Worst)
Carbide Test #2	Sample B→ A→ E →C
Carbide Test #3	Sample G→ B→ E→ F→ D→ C
Duralcan™ Test	Sample G→ B→ A →C

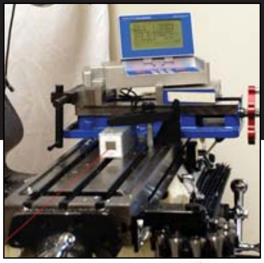
ABRASION TESTS PERFORMED IN LESS TIME AND AT A LOWER COST

This work has demonstrated that an accelerated test can be performed using tungsten carbide as the work-piece material. The ranking of PCD materials was verified by testing the same PCD materials with a conventional work-piece material (**Table 12**). This method has the advantage of allowing abrasion tests to be performed in less time and at a lower material cost than the conventional methods. ■



LARGE LAB-GROWN DIAMONDS NOW ECONOMICAL FOR INDUSTRIAL APPLICATIONS

Sarasota, FL – The Gemesis Corporation has announced that it is now producing laboratory-grown diamonds in sizes over five carats and at prices attractive for industrial users. "With larger sizes and lower prices per carat," explained Stephen D. Lux, Gemesis CEO, "we believe that we are offering industrial users an opportunity to use lab-grown diamonds in applications for which only natural diamonds or lesser-quality materials have been used in the past. Plus, we can saw and deliver to specific requirements." The laboratory-grown diamonds offer many benefits: large crystals, clean material, consistent characteristics, reliable supply, competitive pricing, and environmentally responsible production. Gemesis (www.gemesis.com) invites prospective users to explore opportunities directly with the Company's Vice President of Marketing, Martin DeRoy mderoy@gemesis.com.



NEW 4 AXIS RECEIVER SOLVES INDUSTRIAL ALIGNMENT PROBLEMS

Peabody, MA, June 2009 – Pinpoint Laser Systems® is announcing a new four axis Microgage Receiver that provides useful alignment information for evaluating and correcting machinery alignment problems. The new 4D Microgage Receiver measures two linear axes X & Y and their two angular components yaw & pitch. The two linear axes show how well machinery is aligned along a common centerline and the angular readouts show if parallelism problems are present. The new 4D Microgage Receiver is ideal for aligning lathes, turning centers, spindles as well as moving linear slides, rams and pistons, injection molding machinery, moving mechanical sub-assemblies and more. **For additional information contact Pinpoint Laser Systems at info@pinlaser.com.**

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SP3 DIAMOND TECHNOLOGIES LAUNCHES TUNABLE DIAMOND COATINGS FOR WEAR SURFACES

Santa Clara, CA, July 14, 2009 – sp3 Diamond Technologies, Inc., a leading supplier of diamond film products, equipment and services, today announced that its chemical vapor deposition (CVD) deposition capability has been expanded to provide diamond coatings ranging from super smooth nanocrystalline with a surface roughness of less than 10 nm to controlled microcrystalline films with a surface roughness greater than 10 um. Additionally, sp3's Model 650 CVD diamond hot filament reactors, which are used to apply the coatings, are available for companies interested in manufacturing diamond coated products in-house. sp3's super smooth diamond is ideal for wear surfaces such as seals or bearings, while the microcrystalline films are highly suited for applications such as chemical mechanical planarization (CMP) pad conditioning. **For more information about the company, its products and services please visit www.sp3diamondtech.com.**

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FINITE ELEMENT MODELING USED TO BETTER UNDERSTAND STRESS DISTRIBUTION IN COMPOSITE BODIES

Wire drawing is a process to produce wires to desired tolerances for a wide range of applications. Wires of a wide variety of metals are produced by this method. Typical examples include electrical wire, springs, fencing, instrument wire and tire cord. The process involves reducing the diameter of rods or wires by drawing them through a die, or usually a series of dies. Each successive die has a smaller bore than the one before so that the wire diameter is stepped down gradually during the process. Successive reduction steps help control the deformation that occurs within the wire and reduces the likelihood of wire breakage. The wire experiences adiabatic heating and this, combined with friction energy, exposes the wire and dies to elevated temperatures and thermal gradients. The dies also experience high contact stresses. Therefore, the dies must have material properties such as high hot hardness, chemical stability and wear resistance with respect to the wire material.

Tool steels were historically used to manufacture wire dies until the first half of the 20th century. Tungsten Carbide (WC/Co) became a popular material for wires dies due to its unique combination of hardness, wear resistance and toughness. Both materials are still used today. However, for fine wire drawing, Polycrystalline Diamond (PCD) has developed as a high performance, reliable and cost effective alternative. PCD wears very slowly and imparts a fine surface finish to drawn wire. While harder, PCD is also not as tough as carbide and tool steel. Therefore PCD is often supported by a carbide or steel casing (Fig. 1) that gives the body a higher effective compressive strength and also aids in the ease of mounting the die in a rigid support casing.

PCD wire dies are manufactured by compacting diamond powder along with the carbide casing at high temperature and extremely high pressure. Once sintered, the die (or nib) is ground to precise dimensional tolerances. Then, a conical shaped hole is made in the PCD core by the method of Electrical Discharge Machining (EDM). This creates the entry angle, bore and exit angle geometries commonly associated with wire drawing dies. The die bore so formed is polished in order to reduce frictional effects during wire drawing.

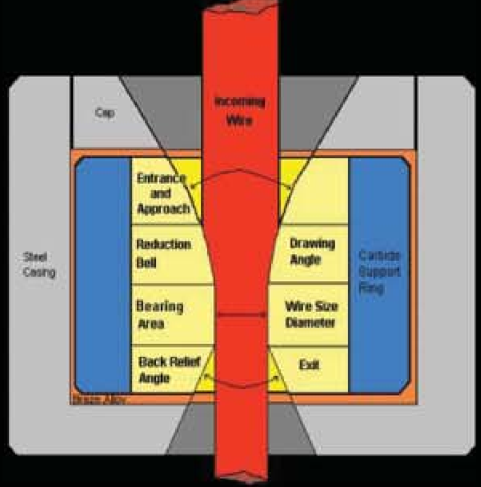
Due to the hardness of the materials involved and the stresses placed on them during processing and application, cracking is a common defect that renders the dies useless. Since cracking is a stress-controlled phenomenon, finite element modeling (FEM) can be used to better understand stress distribution in these composite bodies. The finite element models can then be employed to develop alternative design strategies to manage or reduce inherent stresses.

THE FINITE ELEMENT METHOD

Finite Element Modeling (FEM) is a numerical analysis technique

DEVELOPING CONCEPTS FOR BETTER PRODUCT DESIGN AND PROCESSES

Finite element Modeling (FEM) is a useful tool to model residual stress in composite bodies synthesized by high pressure, high temperature (HPHT) processing. These models can also be used to provide insights into product design and post processing treatments. The residual stresses in a polycrystalline diamond (PCD) wire die encompassed by a tungsten carbide ring was modeled using the DEFORM software package. It was used to analyze the effect of design and processing variables on the resulting residual stress in the PCD wire die. The results were used to develop concepts for better product design and processes. These concepts were tested using the FEM model and compared with a baseline model.



Typical Wire Die Profile

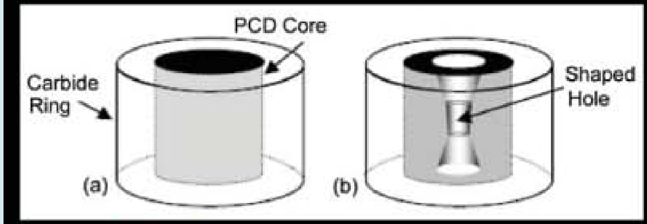


***Figure 1:* Wire drawing dies (a) as-pressed and (b) with EDM machined hole.**

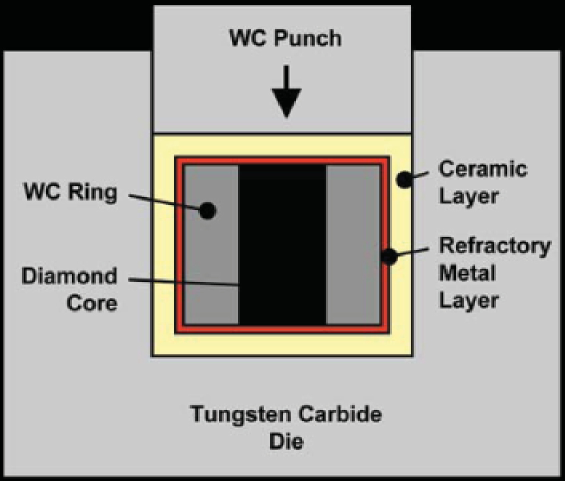
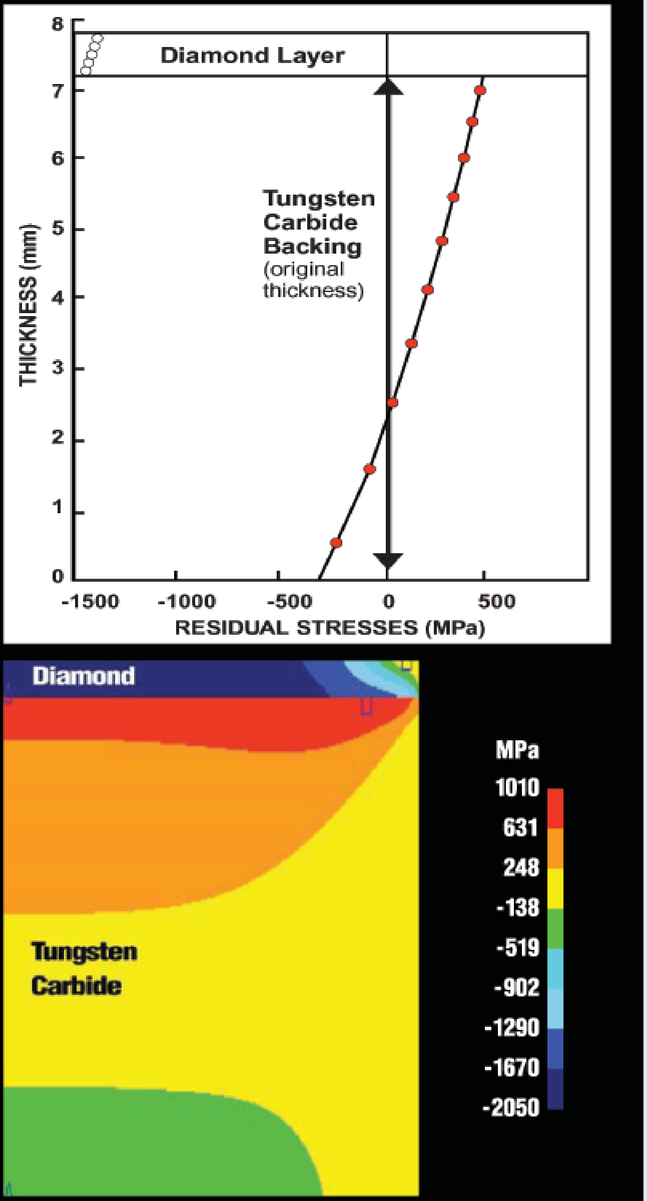


***Figure 2:* Pressing components for PCD-Carbide wire drawing die.**

***Figure 3:* Comparison of residual stresses (Mpa) in PDC cutter. Stresses are resulting from cooling the cutter from 1000∞C.**



in which a complex structure is broken into discrete components wherein the stresses and strains can be mathematically calculated based on known conditions of material properties and applied thermal and mechanical loads. This method is now well established and proven successful for approximating exact solutions to physical problems that would otherwise be impossible to solve analytically. Discretization is the first step in which the solid geometry is divided into finite elements. Material properties are used to determine a force-displacement relationship of the elements under loading, known as the stiffness matrix. Then the loading conditions (pressure, force, velocity) are defined along with the boundary conditions at specified nodes of the matrix. Finally, the stiffness matrix, applied loads and boundary conditions are assembled as a set of equations in a matrix form. Stresses, strains and other quantities of interest can be calculated from the solution of the matrix equations, based on the resulting nodal displacements. Several commercially available software packages (DEFORM', ABAQUS/Explicit', FORGE 2') are used for calculating elastic-plastic deformation and residual stresses under non-isothermal forming conditions.

DEVELOPMENT OF RESIDUAL STRESS IN PCD – WC/CO BODY

PCD dies are normally manufactured by sintering PCD powder at high temperatures (1300 - 1500∞C) and pressures (5 - 8 GPa). As pressure is released and the body cools, stresses develop due to the difference in thermal expansion coefficients between the PCD and carbide materials. FEM has been used to study stresses in Polycrystalline Diamond Compacts (PDC)–WC/Co cutters. The research in previous papers was primarily focused on PDC cutters. In a PDC cutter, the PCD is sintered onto a tungsten carbide cylinder, the PCD being situated directly on top of the carbide. While stresses induced depend on the relative material properties, they also change due to the configuration (applied boundary conditions). To the authors' knowledge, stress analysis for PCD-WC/Co wire dies has not been reported in the literature. Previous models cannot be satisfactorily used to predict the stress state in a wire die having the configuration shown in Figure 1. Therefore, a study was undertaken to develop a FEM model for wire dies and to use the model to study the impact of design and process changes.

MODEL DEVELOPMENT FOR WIRE DIES

The process is considered to have two key phases. Phase 1 is "compaction" during which diamond powder is pressed along with an annular ring of WC/Co by increasing temperature and pressure into the ranges stated above. Phase 2 is "cooling and depressurization" during which pressure is ramped back to zero and simultaneously cooled to room temperature. A pressing system was characterized for the purposes of modeling this type of part that contains the following (see Figure 2):

- PCD CORE – deforms plastically, contains Co binder, assumed to be in solid state during phase 2.
- WC/CO RING – deforms plastically, contains Co binder.
- REFRACTORY METAL LAYER – for isolation of PCD and WC/Co from ceramic layer
- CERAMIC LAYER – deforms plastically, thermal barrier, for pressure uniformity and thermal isolation.
- CARBIDE PUNCH – rigid (does not deform), same properties as WC/Co die and ring
- CARBIDE DIE – deforms elastically, same properties as ring and punch.
- External boundary assumed to be at 100°C.

For any modeling approach there are certain assumptions that must be made so that the model does not become too complex for numerical solution. Iterative solutions of the matrix equations must converge. For this project the following assumptions were made:

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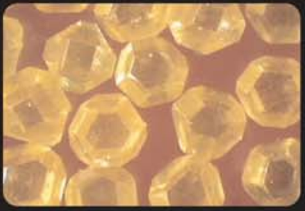

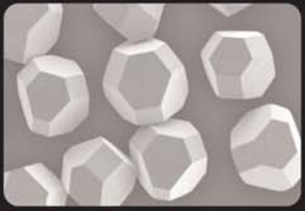

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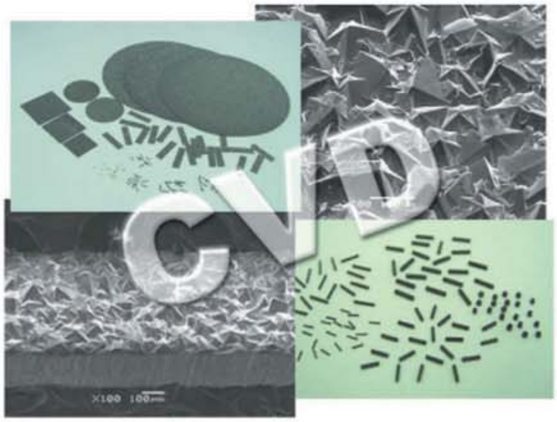

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TABLE 1: Material Properties

	WC/Co			PCD		
	20°C	300°C	600°C	20°C	300°C	600°C
Elastic Mod. (Gpa)	648	579	458	890	890	890
Thermal Expansion Coeff. (x10^{-6}/K)	4.5	5.2	5.2	1.3	2.5	3.9
Poisson's Ratio	0.22	0.22	0.22	0.07	0.07	0.07
Thermal Cond. (W/(cm-°C)	1.0	1.0	1.0	5.43	5.43	5.43
Specific Heat (J/(g-°C)	0.23	0.23	0.23	0.79	0.79	0.79
Density (g/cm^3)	15.0	15.0	15.0	3.51	3.51	3.51

- AXISYMMETRIC PROCESS – the system can be solved using a two-dimensional finite element model.
- Refractory Metal Layer has no effect on deformation due to its thinness.
- PCD core bonds to the carbide ring so there is no relative movement – no constraints on heat transfer between PCD and carbide.
- Ceramic layer behaves like incompressible liquid and distributes and applies pressure uniformly – any elastic deformation of punch and die can be ignored, can be treated as rigid.
- Volume of PCD powder is equal to the volume of the carbide ring cavity.
- All components are incompressible save the PCD core during Phase 1.

As mentioned earlier, it is important to have material property values, especially elastic, that vary as a function of temperature. These are shown in Table 1. Values for properties at higher temperature ranges were extrapolated due to unavailability of hard data. Fine mesh distribution is used for the models, especially for the deformable components: PCD core, carbide ring, ceramic layer.

Flow stress data for WC/Co and PCD were taken from yield stress curves in the ASM Metals Handbook. For the diamond in the powder state in Phase 1, the flow stress is proportional to that in the solid state based on relative density. The FEM code calculates the variations of flow stress data automatically as the density of the PCD changes during the compaction (Phase 1) simulation. The stress response for the ceramic layer is assumed very low since it behaves very much like an incompressible liquid.

CORROBORATION WITH MEASUREMENT

The evaluation of modeling results using experimental data is necessary to assess reliability of the model design, assumptions and boundary conditions. There is a lack of literature for wire dies but some information is available for PDC cutters. Figure 3 includes a comparison of predicted radial stresses with estimated values for an identical design. The figure shows that the predicted and estimated residual stresses have the same trends, that is, compressive residual stresses in the diamond layer and tensile stresses in the WC substrate. The predicted difference in residual stresses at the diamond-WC/Co interface is very close to the calculated difference (~2000 Mpa). Indications are that the modeling approach and material property representations, although not completely robust, provide a good first order simulation of the residual stress state in a PCD-WC-Co body.

RESULTS

After establishing a baseline wire die simulation, several simulations were run to determine the effect of various parameters on the distribution of hoop and radial residual stresses in wire drawing dies. The parameters studied were:

- Chamfering of the inner edge of the carbide ring (at the PCD – WC/Co interface)

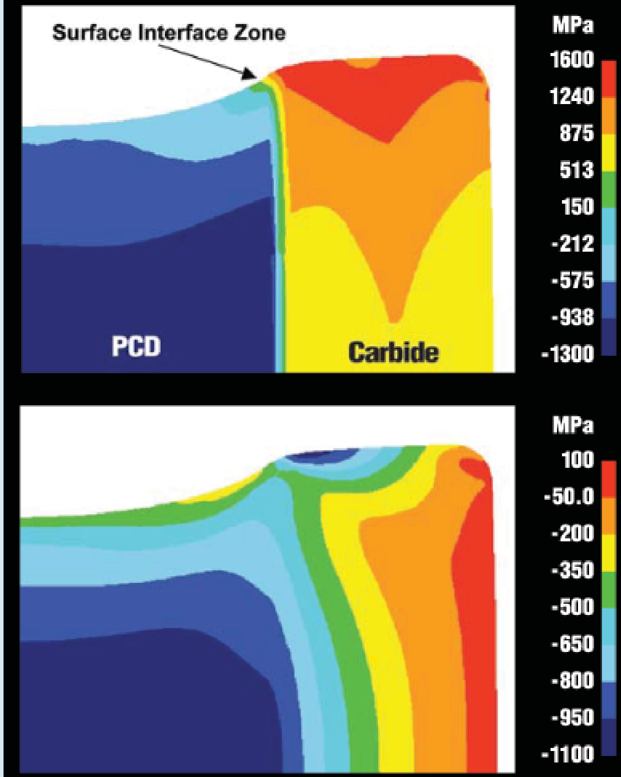
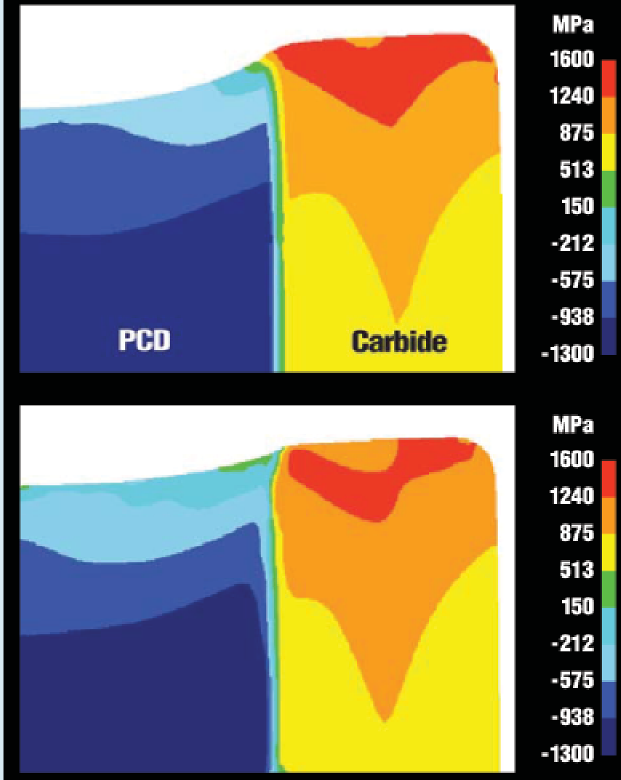


Figure 4: ***Standard die (a) hoop residual stress and (b) radial residual stress***

Figure 5: ***Predicted hoop residual stress for standard die (right) and chamfered carbide ring (left).***



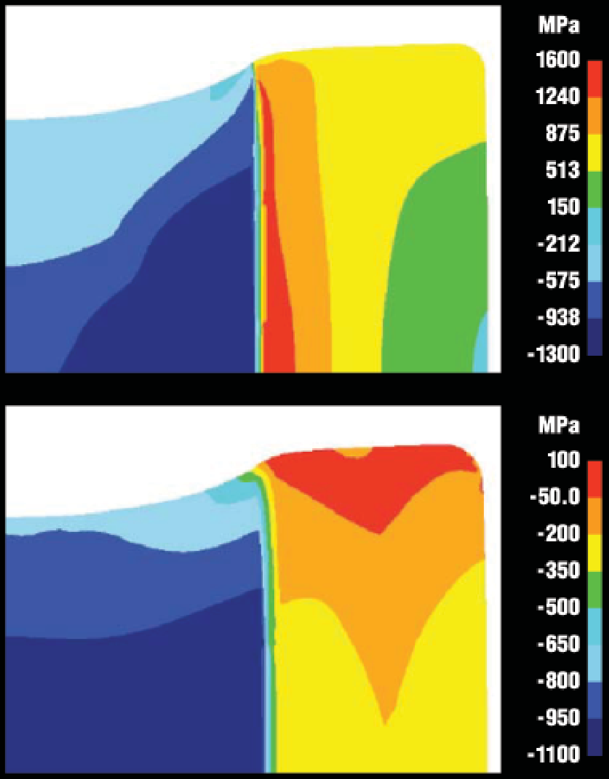
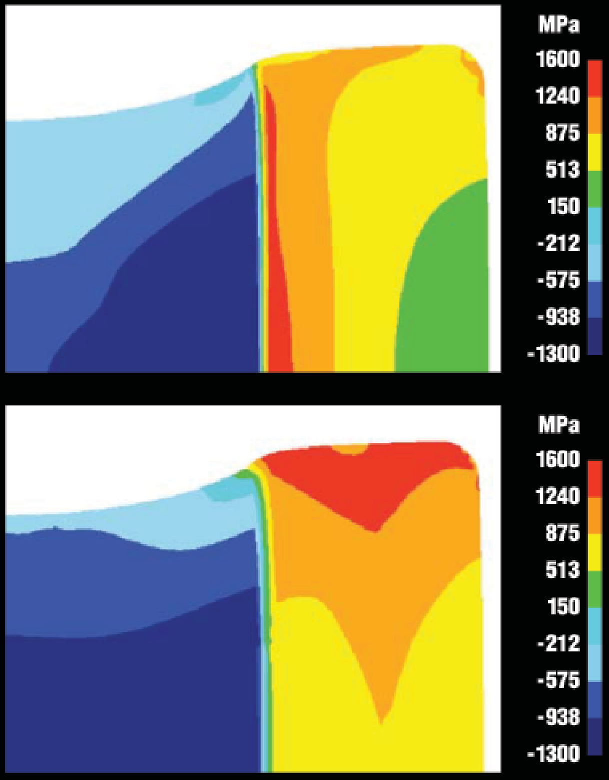


***Figure 6:* Predicted hoop residual stress for standard die (right) and thick-wall carbide ring (left).**

***Figure 7:* Predicted hoop residual stress for standard die (right) and with higher process pressure and longer process time (left).**



- Increase of carbide ring wall thickness
- Varying temperature and pressure process parameters
- Varying the CTE of the WC/Co ring
- Inserting an interlayer between the PCD and WC/Co phases

RESIDUAL STRESSES IN BASELINE DIES

Hoop residual stress in baseline PCD-WC/Co wire dies tend to be compressive in the PCD core and tensile in the carbide ring, primarily due to the larger coefficient of thermal expansion of WC/Co (4.5E-6/K at 20∞C) compared to PCD (1.3E-6/K at 20∞). However, as can be seen in Fig. 4a, tensile hoop stresses exist in the PCD core near the interface with the carbide ring. Cracking (in a radial direction) initiating in the PCD core is very possible due to these stresses. Conversely, radial stresses for both the PCD core and carbide ring are primarily compressive, the desired state to subdue crack initiation and propagation (Figure 4b). The interface between PCD and carbide is the region of largest stress gradient and is therefore a critical area for crack initiation and propagation. The free surface interfacial region is most critical since PCD shrinkage, due to consolidation during pressing, causes local tensile stress in the PCD in this region (See Figure 4a). The remainder of this paper will focus on methods for improvement of the hoop stress condition.

EFFECT OF CHAMFER

It was considered that introducing a chamfer could help redistribute stress in the surface interfacial zone. A chamfer of 20∞ was simulated on the carbide ring near the interface with the PCD core. Figure 5 shows that this chamfering has a positive effect on hoop residual stress in the PCD core. The neutral stress zone is expanded and tensile stress within the PCD is locally reduced. However, there is still a sharp gradient across the interface so the improvement is considered marginal.

EFFECT OF CARBIDE RING WALL THICKNESS

In theory, a larger mass of carbide could help contain stress effects by giving gradients more volume for distribution. To simulate this, the stress distribution was calculated for a die with a 20% increase in carbide ring wall thickness. Figure 6 illustrates predicted hoop stress in the baseline wire drawing die and one with increased carbide ring wall thickness. It can be seen that the carbide wall thickness has a significant effect on the residual stress distribution. The hoop stress shifts from an axial to a radial orientation. This reduces the driving force for crack propagation outward from the interface. The overall tensile stress in the carbide is also reduced.

INFLUENCE OF PROCESS CONDITIONS

Key parameters such as time, temperature and pressure can be modified to try to affect the final stress state. Annealing (time, temp.), for example, is a well-known method to reduce residual stress in many metal-formed parts. Here, pressure and time have been modified to study the effect on stress. The effects of process conditions (pressure and temperature profiles) were examined by increasing the effective pressure and increasing time at sintering temperature compared to the baseline simulation (Figure 7). There is a shift toward compressive stress in the carbide ring and also a shift in stress gradient orientation. The hoop stress gradient in the baseline die is largely axial while the modified process condition die has a radial orientation. As in the case of increased ring size, this latter orientation is likely more favorable for crack control since the tendency is for a crack to drive toward the zone of highest tensile stress in the presence of a stress gradient. Since cracks can initiate at or near the PCD – WC/Co interface, there is more resistance to cracks propagating outward in the case of the radial stress gradient.

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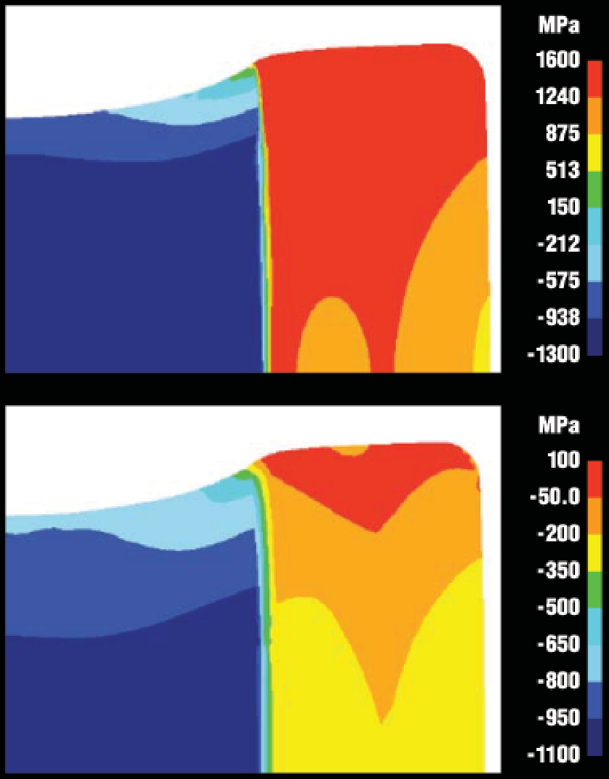
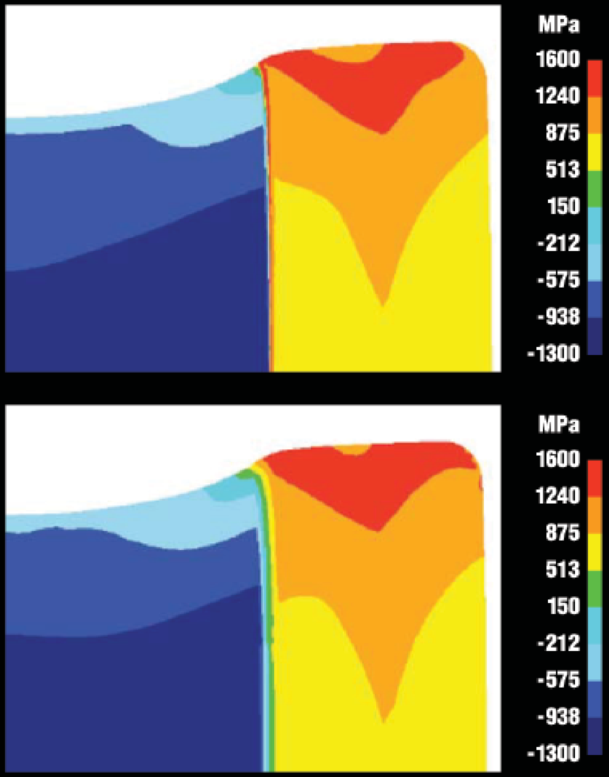


Figure 8: *Predicted hoop residual stress for standard die (right) and dies with higher Co content (left) (25% higher value for CTE).*

Figure 9: *Predicted hoop residual stress for standard die (right) and dies with a tantalum interlayer between the PCD core and carbide ring (left).*



EFFECT OF MODIFYING CARBIDE CTE

Intuitively, to reduce cracking, one might select a higher level of cobalt in the carbide ring, expecting the increased toughness to be better for crack resistance. In this study increasing the CTE of the carbide by 25% simulates an alternative grade of carbide. This represents a grade of carbide with significantly higher cobalt content. Figure 8 shows the hoop stress for the baseline and modified condition. This effect expands the zone of highest compression within the PCD core but also expands the zone of highest tension within the carbide ring. Increased tension in the carbide is undesirable as is the overall increase in residual stress gradient within the body. The modification also effectively increases the sharpness of the stress gradient across the interface, another undesirable feature. These results suggest that selecting a carbide grade with lower cobalt content could be beneficial, reducing the difference between CTE's and reducing the induced residual stress.

EFFECT OF INSERTED LAYER AT THE PCD – CARBIDE INTERFACE

Another concept to reduce the severity of the stress gradient could be to insert a layer of intermediate CTE between the carbide and PCD. For this simulation, a relatively thick (100 um) layer of a refractory metal with intermediate CTE was modeled. The insertion of a refractory metal layer between the PCD core and carbide ring is predicted to have little effect on the hoop stress and the stress gradient across the interface is still seen to be very sharp (Figure 9). However, this model does not take into account the effect of such a layer on diffusion across the interface, reaction of the metal to form a carbide, or the malleability of the layer and its ability to shift under pressure.

CONCLUSIONS DRAWN FROM MODELING STUDY

This study has yielded a model to predict residual stresses in "as-formed" PCD-WC/Co wire dies. The model can be used to test various geometrical and/or property modifications to study their effects on the stress state within the die. If the stress state can be controlled to reduce the initiation of cracks within these very hard phases, then catastrophic failure of dies can be reduced in the forming stages and, more importantly, during wire die finishing and application. An understanding of the material properties of the various materials involved and the effect of the sintering process on these material properties is critical to development of the model. Comparison of the model with experimental results is also important and in this case the model was tested against results in the literature for PDC cutters. This validated the collected material properties and assumptions made for a body with these two phases (PCD and carbide) and containing a sharp interface between the two. Once validated, the modeling approach was used to test modifications to geometries and material properties of the wire die system and their effects on the residual stress states. Carbide chamfering, carbide wall thickness, process parameters (temperature and pressure), carbide grade and insertion of a layer at the interface were studied. In summary it was found that:

- Process modifications (extended time and increased pressure) and increasing carbide ring size were most effective in changing the stress profile in a positive way; i.e., shifting toward an overall more compressive state. Most importantly, tensile stress is reduced within the carbide ring.
- Higher cobalt containing carbide increases tensile stresses within the carbide ring due to the larger difference in CTE between the PCD and the carbide. The opposite approach (lower Co containing grade) would be more favorable for controlling stress.
- Chamfering, and an interfacial layer were predicted to have little effect on the stress profile. ■

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Effect of Cycling the High Pressure and the High Temperature on the Quality of Cubic Boron Nitride Composites

By: **Sergio N. Monteiro, Guerold S. Bobrovinitchii and Ana Lucia D. Skury**
State University of the Northern Rio de Janeiro, UENF, Advanced Materials Laboratory, Brazil

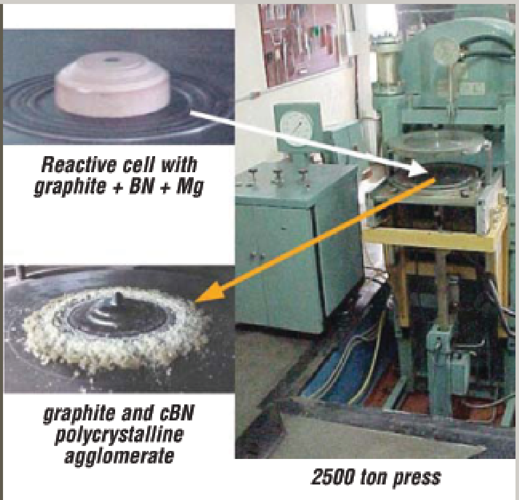
NEW TECHNIQUE IMPROVES HPHT PROCESSED CBN COMPOSITES

Owing to non-stable conditions generated during conventional HPHT sintering of cubic boron nitride (cBN) composites, it is not possible to predict both the yield and quality of the final product. Moreover, the particle size and amount of binding compounds that are associated with the composite may be responsible for defects and residual stress. In the present work, a novel technique of automatic cycling the pressure and the temperature was applied to the sintering of cBN composites bound with Ti2N and Al. This type of processing permitted a more uniform structure for the composites with ultra-fine layers of the binding compounds separating dispersed cBN grains. The technique improved the adhesion between the phases and contributed to the decrease in both the residual stresses and interfacial defects. As a consequence, the productivity related to machining of hard steels using inserts made of cycling HPHT processed cBN composites was increased.

Present Work Based on Published Data and Current Experiements

The technological development in association with the efficiency of the metal-mechanical industries are directly related to the application of new types of wear resistant cutting tool materials. Among these, cubic boron nitride (cBN) stands as one of the most commercially, applied being surpassed only by diamond in terms of hardness. Nowadays, the main use of cBN is for high-speed machining of ferrous metals such as high-strength tempered alloy steels with hardness above 50 HRc. Therefore the use of cBN extends much beyond that of other materials, particularly in areas for which diamond tools cannot be cost-effectively applied. The ever growing demand for high performance as well as the dimensional restrictions and life-time of machine elements and system components are motivating the development of very hard materials that exhibit difficult machining and finishing. Until recently, almost all surface finishing operations in the metal-mechanical industrial sector, was accomplished by milling. However, this type of operation is not always convenient in terms of material technical aspects, owing to low productivity, the possibility of undesirable structural changes in surface layers and generation of residual stress. Moreover, the relatively high cost as compared to other machining operations represents an important economic disadvantage. For some cases a possible solution is to replace the conventional wear resistant material with inserts of polycrystalline cBN materials. In this case advantages are obtained in machining. It is relevant that in the first years following the synthesis of cBN, the industrial sector failed to notice the practical potential for use for this material. Only in the 70´s was attention paid to the important fact that cBN is not affected by the relatively high temperatures generated in the machining process. cBN became a promising material for metal-mechanical operations especially those involving tempered steels and cast irons. Thereafter, cBN begin to replace conventional tool materials for difficult machining or for applications on materials where diamond tools could not be employed cost effectively.

The favorable technical and economic reports for polycrystalline cBN as compact inserts for machining operations on high strength alloy steels and hard metals (composites hardened with carbides) resulted in a significant worldwide consumption of this superhard material in several branches of the metal-mechanical sector. In the 90´s cBN and its composites had already grown almost 20 times. However, the current industrial technology for cBN composites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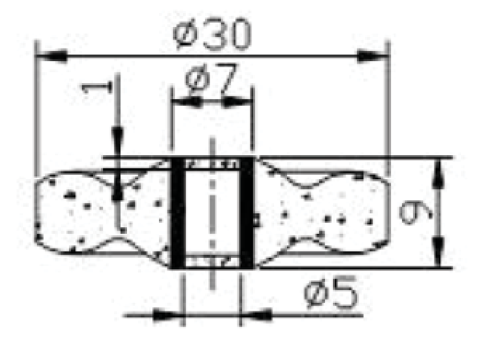

Figure 1 **– Schematic of a deformable capsule mounted with reactive mixture**

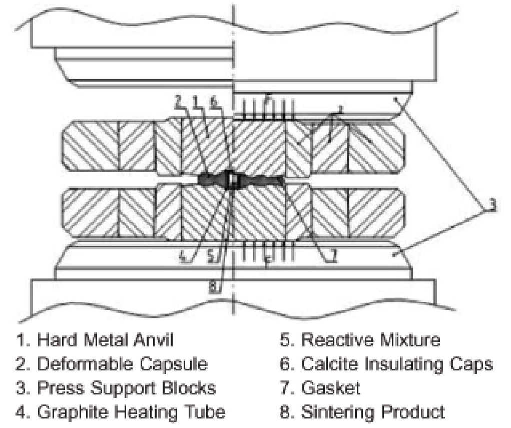

Figure 2 **– Positioning scheme of the capsule within a HPD. A) Open position before compression; b) closed position during the compression.**

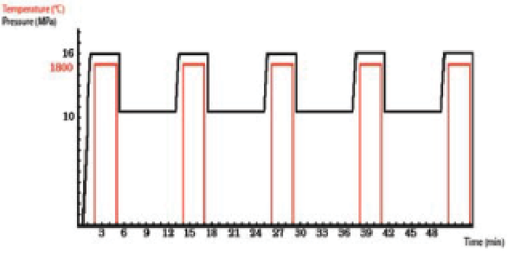

Figure 3 **– New schematic diagram for cyclical sintering parameters application.**

production does not allow a serial fabrication of cutting compacts by sintering process. Here it is important to mention that for the sintering of these composites one should use cBN powder with or without a binding agent. Normally the amount of binding varies in the range of 10 to 40%. In addition to its major function of connecting the crystalline particles, this agent must also dissolve the boron oxide layers that are formed on the surface of the cBN crystals that impair the connection between them during the sintering process.

Several binding agents have been employed, the most common being aluminum and titanium based compounds. According to the amount of crystals, the cBN compact can be classified as high content (~90wt% of cBN) or low content (~60wt% of cBN). The latter is the tougher one. In the present work the development of a new technology for fabrication of cBN compacts is based on published information and experimental data obtained here.

The Experimental Procedure

Cubic boron nitride composites were prepared according to the following sequence of operations:

1. Sieving of aluminum powder to sizes in the ranges 150/180 µm.
2. Sieving of Ti2N powder to a size of 40 µm.
3. Mixing of 30wt% Al powder and 70wt% Ti2N powder to act as binding agent.
4. Mixing of 90wt% of cBN powder with 10wt% of binding powder to form the so-called reactive mixture.
5. Placing the reactive mixture inside a graphite heating tube, which was then mounted inside a deformable capsule by 20kgf of compression force, as schematically shown in Fig.1.
6. Placing, Fig.2, the deformable capsule in the center and between the working surface of an anvil with toroidal concavity type of high-pressure device (HPD).
7. Placing the HPD between the main compression cylinders of a hydraulic press with 630 ton of capacity. The set was calibrated in relation to the high pressure and high temperature attained inside HPD.
8. Turning on the press in a way to obtain and maintain the pressure (P) and temperature (T) parameters required to complete sintering after 3 minutes. The control of the process was based on the chosen P = 7.7GPa and T = 1800oC this was carried out by taking into account the command diagram for both common and cyclic operations as illustrated in Fig.3.
9. Decreasing the temperature at the end of the process and then releasing the applied pressure.
10. Disassembling the HPD and recovering the deformable capsule.
11. Breaking the capsule as well as the graphite heater tube and the insulating caps to recover the cBN composite
12. Cleaning of the compact composite by ultra-sound, inside a detergent solution for 10 minutes.
13. Grinding the surfaces of the cBN compact for required finish.
14. Measuring the hardness of the cBN.
15. Scanning electron microscopy of the cBN structure.
16. X-ray analyses
17. Inserting the cBN compact as a tool bit for machining tests.
18. Testing the cBN compact bit by machining 4140 steel of 52-56 HRc. The machining parameters were chosen as those for a ring shaped piece.

The schematic diagram in Fig.3 shows the cyclic variation of the pressure and the temperature with processing time. This diagram was established in the computer-controlled command coupled with the press system for applying pressure and temperature to the reactive mixture. The cycling pressure was performed by alternating two different levels 7.7 GPa at 1800oC for 3 minutes and 4.5 GPa at 30oC (room temperature) for 3 minutes. These cycles were repeated five times for a total of 54 minutes. This cycling procedure for applying pressure and temperature was decided based on the supposition that it would result in a martensitic structure in the binding and produce a closer position of the cBN particles with respect to each other.

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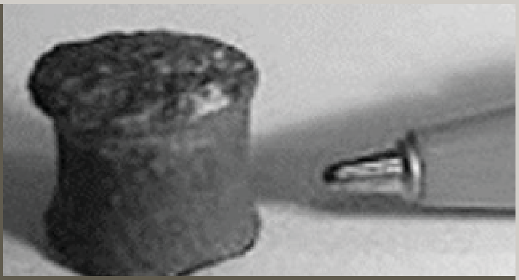

Figure 4 – Ilustration of a cBN compact composite.

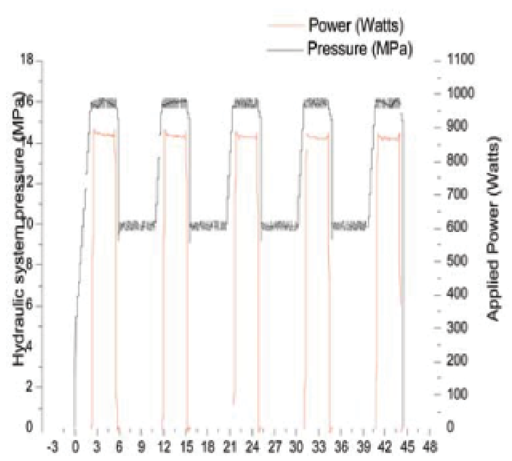

Figure 5 –Graph with computer registration curves for the sintering parameters of an actual sample.

Results and Discussion

Figure 4 presents a typical sintered cBN compact composite obtained by the cycling process and the parametric values of the diagram in Fig.3. The typical dimensions of these cylindrical compacts were: diameter of 4.0-4.5 mm and height of 4.8-5.1 mm.

In addition to the cyclic process, Fig 3, a constant process at 7.7 GPa and 1800oC for only 3 minutes was also used. However, in this constant process the percentage of defect-free sintered compacts was below 78%. By contrast, for the cyclic process 100% of the samples, i.e. all of them, were defect-free. The computer-controlled command permitted tracking in real-time the variation of the applied parameters to the samples during the sintering process. Therefore it was possible to estimate the actual high pressure and high temperature attained inside the HPD by comparison with calibration curves simultaneously performed. Figure 5 illustrates the graph with actual curves recorded by the commanding computer, corresponding to the variation of the process parameters during a typical sintering cycling experiment for a composite sample with 250/300 μm of granulometry. Regarding this figure, it should be mentioned that the pressure value around 7.7 GPa, with a precision of ±0.6 GPa, is a consequence of the small oscillation, Fig.5, in the applied pressure through the press main cylinders.

It should also be mentioned that the attained temperature, by electrical heating, was approximately 1750oC. The curve corresponding to the electrical power in Fig.5 is represented by a declining plateau possibly related to the phase transformation of the cBN and other materials inside the HPD. During the cyclic period in which the electric current was turned off, the pressure was kept, Fig 5, in a level of 4.6 GPa. To measure the hardness of the sintered cBN compact composites, a Vickers indenter was used under a load of 30 kg. In general we can affirm that: It is very difficult to obtain a perfect indentation. Owing to the low plasticity of superhard material, cracks always occur at the tips of the diagonals resulting in great imprecision for the hardness measurements. The opaque surface of the cBN reflects only a small amount of light, which impairs the observation of the indentation mark. The obtained values for the hardness were found to vary from 22 to 35 GPa for the constant process (common sintering) and from 32 to 50 GPa for the cyclic process.

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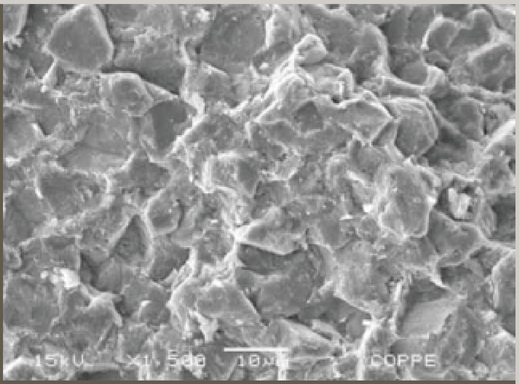

Figure 6 **–SEM fractography of a cBN compact composite obtained by constant pressure processing.**

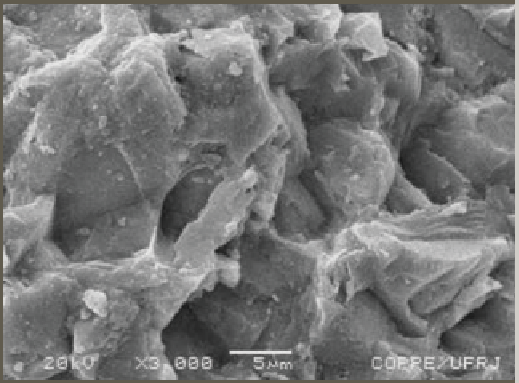

Figure 7 **–SEM fractography of a cBN compact composite obtained by cyclic process.**

Here it is important to comment that commercially available cBN composites display hardness values in the range of the 40 to 50 GPa. It should also be noted that other authors recommend the Knoop hardness since this type of hardness measurement promotes lower deformation on the composite surface. The structure of the compact composites was analyzed by scanning electron microscopy (SEM) in diametrically ruptured samples. SEM images of the fractured regions for both common and cycled samples are shown in Fig. 6 and 7, respectively. In Figure 6, the fracture corresponds to a sample processed at a constant pressure, i.e., without cycling parameters. In this figure, it is important to notice that rupture occurred mostly in the boundaries between the matrix, composed of binding material, and the cBN particles. This means that the adhesion force between the binding compounds and the cBN particles is relatively weak.

In Figure 7 the fracture corresponds to a cyclic processed sample. In this figure one should note evidence of intergranular fracture, which occurred separating crystalline grains that form the cBN particles. This is an indication of a more effective adhesion between the cBN particles and the binding compounds that form the matrix of the compact composite. Apparently, the cyclic process, schematically presented in Fig. 3, is associated with an efficient chemical bond owing to reactions between the cBN particles and the matrix. It is suggested that the longer time of the cyclic process as compared to the common sintering at constant pressure is the responsible for stronger adhesion forces.

Figure 8 presents x-ray diffraction patterns recorded in a model URD 65 Seifert equipment using Co radiation. In this figure for the cyclic processed compacts, the identified peaks revealed that, in addition to the initial phases originally existing in the reactive mixture such as cBN, Al, Al2O3 and Ti2N, other new phases particularly TiB2 and TiN and AlN also occurred. Among these new phases TiN and ALN are known to contribute to the formation of the binding matrix surrounding the cBN particles.

Wear tests to evaluate the performance of the cBN compact composites as tool bits were performed in a model TORMAX 20A Romi lathe. The selected operational parameters were those recommended for machining high strength alloy steels. These parameters were 1768 m/min of cutting speed, advance of 0.05 mm without cooling fluid. After each pass, the steel piece was evaluated in

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Industrial Diamond Association of America, Inc.

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Which applies to your company: ______ Corporation ______ Partnership ______ Sole Proprietorship

Provide names of principle officers or partners: ______________________

When was your company established? __________

How long has your company been engaged in superabrasive/ultra-hard material industry? _______

List at least two business references, preferably one is an IDA member (name, company and address of each):

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2. ______________________

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Any company and/or individual classified as a superabrasive/ultra-hard material supplier, tool maker, machine tool builder, end user or related business with offices in the USA, Canada or Mexico is eligible in this category. Only one individual shall be designated by each member company as the IDA Delegate with voting and other privileges described in the By-Laws.

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Available for any individual who has retired or is no longer active in the diamond or cbn business, but wishes to receive information mailings and attend IDA meetings as a member. Annual fee for Senior Member is **$50 per year**.

WHAT IS THE IDA?

The Industrial Diamond Association of America, Inc. **is a non-profit trade association and was incorporated on March 29, 1946 in the State of New York. It is the oldest and most prestigious association in the superabrasive/ultrahard materials industry. Activity and focus has evolved from natural diamond to superabrasives and most recently, to all ultrahard materials including CVD Diamond. Members include material suppliers, tool manufacturers, component producers, machine tool builders, end users, academia/research affiliates and other companies related to the research, manufacture, application, use and sales of superabrasives.**

WHAT DOES THE IDA DO?

- **Oversees Statistics Reporting Program**
- **Establishes Industry Standards**
- **Interacts With Global Associations And Organizations**
- **Creates And Distributes Market Studies & Data**
- **Organizes And Presents Technical Seminars & Conferences**
- **Serves As A Government Liaison For Industry Guidelines And Regulations**
- **Participates As Member Of World Diamond Council**
- **Provides Safety / Regulatory Reports And Advisement**
- **Resource For General Information And Consultation**

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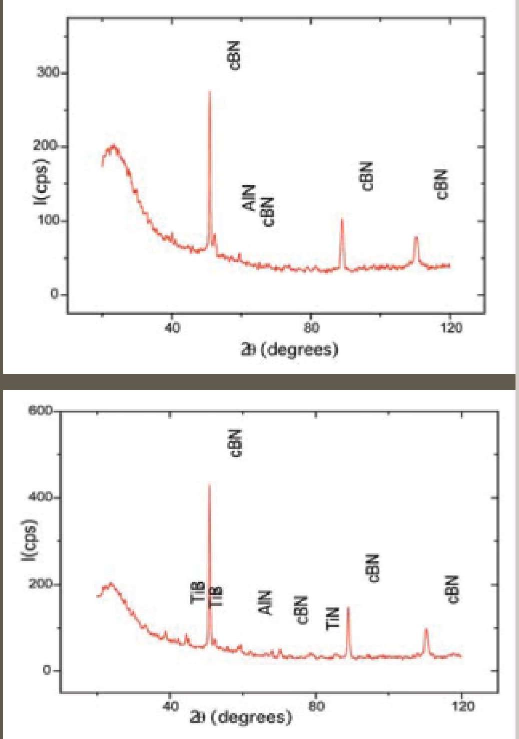

Figure 8 **– X-ray spectrum of a cyclic processed cBN composite.**

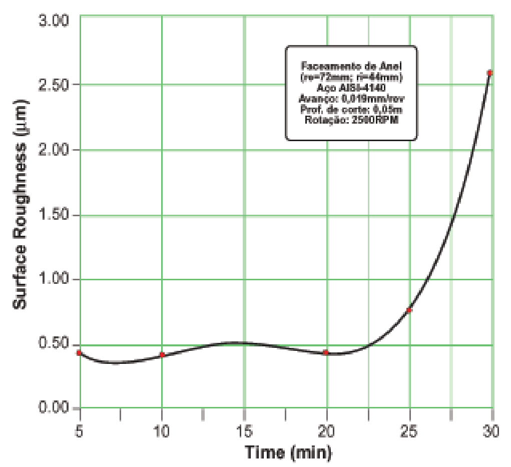

Figure 9 **– Surface roughness of AISI 4140 steel machined with a cyclic processed cBN composite bit.**

terms of surface roughness with a model SJ-201 Mitutoyo rugosimeter. The change in roughness was interpreted as a consequence of the tool bit edge wear up to the end of its operational lifetime. Figure 9 shows the variation of the roughness of a AISI 4140 steel ring, which was machined with a cyclic processed cBN compact composite bit, as a function of the machining time.

In this figure, it is observed that the life of the cBN composite bit, under the imposed operational conditions, can be considered as 25 min. This represents the moment that the roughness becomes greater than 0.5 mm and no further preparation of the bit by changing cutting angles and edges was conducted. Figure 10 displays the variation of the weight of the cBN compact composite bits with machining time for a common sintered sample (1) and a cycled processed sample (2). In this figure it is important to stress the fact that sample (1) processed at constant parameters suffered an intense loss of weight, associated with surface wear, in the first two minutes. After that, there is an almost continuous wear. By contrast, the cyclic processed sample (2) took 8 minutes for its intense loss of weight but then did not suffer any further wear for the duration time of the machining test. This is a surprising result that evidences the much better performance of cyclic cBN composites as cutting tool in comparison with similar conventionally sintered composites. As final remark, it is relevant to mention that the first attempt conducted in this work to produce defect-free cBN compact composites for cutting tools resulted in a material with superior performance. Thus, the present work provided a preliminary indication that this novel technology of HPHT cyclic sintering process developed for cBN composites can be applied to practical operations after necessary industrial adjustments and adaptations.

Better Performance Results for cBN Composites Manufactured with a Cyclic Process

The cyclic high pressure and high temperature production of cBN compact composites was found to be a more efficient process with technological advantages over the common, constant conditions, sintering. All cyclic processed cBN composites were defect-free versus less than 78% of common sintered composites. Moreover, the cyclic processed are 40% harder than the common sintered composites. Microstructure analysis revealed that the cyclic processed composites present evidences of relatively stronger adhesion between the cBN particles and the binding matrix. Furthermore, x-ray characterization indicated that new phases formed after cyclic sintering are responsible for this stronger adhesion. Wear tests simulating practical machining of high strength steel using cBN compacts as tool bits showed a better performance of the cyclic process as compared to the common sintered composites. Therefore, this novel sintering technology has a potential to be applied in industrial operations. ■

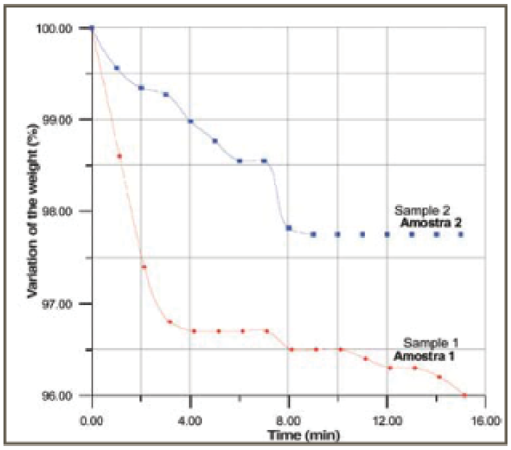

Figure 9 **– Variation of the weight of the cBN compact composite bits.**

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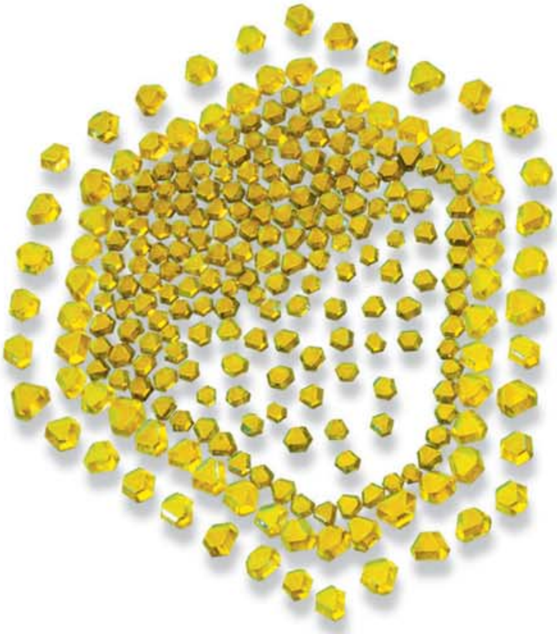

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